EFFECT OF DEFECT LENGTH UPON BURST CAPACITY OF COMPOSITE REPAIRED PIPE

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Sistem saluran paip adalah salah satu infrastuktur yang amat penting dalam industri petrokimia kerana ia digunakan untuk mengangkut petroleum dan gas. Walaubagaimanapun, kerosakan dan kemerosotan paip akan berlaku beberapa tahun selepas ia digunakan, terutama berlakunya pengaratan pada saluran paip yang akan menipiskan ketebalan saluran paip dan kekuatan paip dan seterusnya menyebabkan kegagalan apabila baki kekuatan paip tidak mampu menahan tekanan operasi saluran paip tersebut. Oleh itu, kerja pembaikan paip amat diperlukan untuk menambahkan kekuatan paip, contohnya, dengan menggunakan komposit polimer diperkuat gentian (*FRP*). Kod pembaikan yang digunakan untuk menentukan baki kekuatan paip yang berkarat tidak memasukkan geometri kepanjangan dalam pengiraannya yang amat berbeza dengan kod penilaian. Dalam kajian ini, tekanan letus paip yang diperbaiki komposit akan dikaji dengan pelbagai kecacatan kepanjangan yang berlainan. Kajian ini dijalankan dengan mengunakan kaedah analisis unsur terhingga pada pelbagai paip yang mengalami kerosakkan dengan saiz panjang yang berlainan. Keputusan telah menunjukkan bahawa perbezaan tekanan paip ialah 15.59% dan ini telah menunjukkan bahawa geometri kepanjangan mempunyai kesan pada tekanan letus paip yang diperbaiki komposit. Penemuan ini sangat berguna untuk mengoptimumkan reka bentuk sistem pembaikan yang sedia ada.

ABSTRACT

Pipeline system is one of the infrastructures that are essential in petrochemical industries as it is uses to transport oil and gas. However, pipelines will start to damage and deteriorate after being used for some years, especially the happening of corrosion which will reduce the thickness of pipeline and the remaining strength of the pipe and consequently lead to failure once the remaining strength unable to withstand operating pressure of the pipeline. Hence, additional strength from repairing job needs to be provided, for instance, by using fibre-reinforced polymer (FRP) composites. Unlike the assessment codes, the repair code that use to determine the remaining strength of the corroded pipe does not include the defect geometries such as defect length. In this study, burst pressure of the composite repaired pipeline with different defect lengths and the effect of the defect length upon the burst capacity of composite repaired pipe is investigated. The study is carried out by a finite element analysis (FEA) on various defective pipe with different defect length size. The results show that the difference of the burst pressure subjected to various defect length is 15.59% and this had proved that there is an effect of defect length upon the burst capacity of composite repaired pipe. This finding can be very useful for optimizing the existing repair design.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

D	*Outer Diameter of Pipe*
t	*Pipe Wall Thickness*
σ_y	*Material Yield Strength*
σ_u	*Ultimate Tensile Strength*
σ_a	*Axial Stress*
σ_r	*Radial Stress*
σ_h	*Hoop Stress*
L	*Defect Length*
d	*Defect Depth*
r	*Radius of Pipe*
w	*Defect Width*
P	*Burst Pressure*
M	*Bulging Stress Magnification Factor*
t_s	*Remaining Wall Thickness*
P_s	*Maximum Allowable Operating Pressure*
s	*Specific Minimum Yield Strength*
ε	*Maximum Strain*

LIST OF ABBREVIATIONS

FEA	*Finite Element Analysis*
FRP	*Fibre Reinforced Polymer*
CFRP	*Carbon Fibre Reinforced Polymer*

CHAPTER 1

INTRODUCTION

1.1 Overview

Pipelines act as a transport element in petrochemical industry which normally use in offshore and placed underground. This infrastructure is important in human life, it help in delivering oil and gas that has been produced into different products that we used. For instance, the heat supply for stoves, fuel supplies for transportation and run the machine to make the household product. The study of National Association of Manufacturers (NAM) had also estimated that the crude oil pipelines alone created over 200,000 jobs and over $21.8 billion in Gross Domestic Product in 2015 (National Association of Manufacturers, 2015). This had shown that pipeline infrastructure is also important in moving the country's economic (Lim et al., 2015).

There are a lot of pipeline accidents all around the world over the years including United States who has the longest network of pipeline in the world with 240,711km of the pipeline network is used to transport the petroleum products and 1,984,321 km in transporting the natural gas to make the total length of 2,225,032km (Central Intelligence Agency, 2013). After years in service, pipeline will experience deterioration and a deteriorated pipeline may subsequently fail if no proper action is taken. Hence, monitoring and inspecting of pipeline will be carried out to discover the failures or the deterioration of the pipeline system. One of the common ways for pipeline inspection is done by intelligent pigging to gather important data of the pipeline such as location and geometries of defects. Without carry out the inspection and repairing work of the pipe, the deterioration of the pipeline may cause pipe failures such as leaking and explosion.

1.2 Background of Study

The environment surrounding the pipelines will cause defect on the pipelines due to several factors and subsequently affect the service strength and its service life. There are several types of defect in the pipelines system which include the geometrical defect, defect in metal loss, planner discontinuities and change in metal, and all of these defects will bring effect to the pipelines system (Abdel-Alim, 2018). All of these defects will affect the remaining strength of the pipeline and its service life and performance.

There are a lot of method to repair the defect or the deterioration of the corroded pipeline. Fibre-Reinforced Polymer (FRP) composites is one of the effective repair methods in repairing defective pipeline system. FRP composites are lightweight, high performance, suitable to ocean environment, long-lasting and easily to be constructed and tailored to different requirements (Lee and Jain, 2009). However, the performance of this repair system is not fully understood due to several issues which include the complexity of surface preparation, delamination and de-bonding between steel pipe and composite, performance and contribution of the infill material, load transfer mechanism, effect of defect geometries and conservativeness in existing design codes (Lim, 2017). People will have better understanding on the behaviour on the composites by discovering up these issues and this could help to maximise the role and uses of the composite repair system.

1.3 Research Problem

Corrosions could occur at any places of the pipeline including internal and external surfaces of the pipelines and this will reduce the pipe thickness and reduce its strength due to the loss of metal. A low remaining strength may cause the failure of the pipeline and burst may be occurred.

Data such as the presence and the location of the corrosion happened in the pipe or other irregularities on the wall can be taken from the inspection by using the intelligent pig. From the data that are collected from inspection action, it can help in determining the remaining strength of the defective pipeline by referring to several engineering design codes. These include American Society of Mechanical Engineer (ASME) B31G, modified ASME B31G and DNV-RP-F101 codes. The input parameters that are used in these codes include outer diameter of the pipe, D, wall thickness, t, yield strength of the material, σ_y or ultimate tensile strength, σ_u, the length of the defect, L and the defect depth, d.

However, the repair codes include ISO/TS 24817 and ASME-PCC2 which are used to determine the repair material only include defect depth as the input parameter in determining the remaining strength of the defective pipe. Hence, investigation on other defect parameters such as defect length is needed to explore the potential effect of defect length towards the burst capacity of a composite repaired pipe.

1.4 Research Objectives

The aim of this study is to investigate the effect of defect length towards burst capacity of composite repaired pipeline. In order to achieve the aim, two objectives are established as follow:

1) To determine the burst pressure of the composite repaired pipeline according to different defect lengths.

2) To investigate the effect of defect length upon the burst capacity of composite repaired pipe.

1.5 Research Scope

The scope of this research concentrates about the effect of remaining strength and the burst capacity of the composite repaired pipe subjected to different lengths. Simulation method which is finite element analysis (FEA) was used where finite element (FE) models were developed to determine the burst capacity of composite repaired pipeline. Variation of other defect geometries such as width and depth are not included in this study.

1.6 Importance of Study

Repair cost can be reduced by reducing the usage of the composite wrap on the damage pipelines. One of the challenges in optimizing the composite repair design is the lack of information on the behaviour of the composite repaired damaged pipes. Base on the existing assessment codes and previous studies, the defect lengths has been proven to be influential on the remaining strength and the burst capacity of the damaged pipes.

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